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THE AVON: FAUNAL AND OTHER NOTES ON A DYING RIVER IN SOUTH-WESTERN AUSTRALIA

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INTRODUCTION

In the course of general studies on the freshwater molluscs of Western Australia, it became apparent that very little information was available, either in museum collections or published records, about the mollusc fauna of the Avon River. This was unexpected because the Avon is one of the major rivers of the South-West Region and could have been expected to contribute prominently to any study of the aquatic life of the area. In seeking to account for this discrepancy, evidence has been obtained which suggests that, since the turn of the century, the original aquatic environment and fauna of the Avon have been subjected to a variety of disturbances of increasing severity. These, so far as they affect the molluscs, have reached catastrophic proportions and local extinction now seems distinctly possible for some, if not all, of the original fauna. Paradoxically, the environmental changes that have harmed these species have facilitated upstream expansion into the Avon of what appears until recently to have been a wholly estuarine mollusc. The reason for these changes seems to lie with the near-complete alienation of land for agriculture in the drainage basin and the absence of any kind of conservation-management policy that would recognize the need to protect the riverine environment and biota.

The inland boundary of the Avon drainage basin is not readily definable, varying according to seasonal fluctuations in the amount and distribution of rainfall. Theoretical maximum boundaries are depicted by Bettenay and Mulcahy (1972: 360, Fig. 1), who recognize a topographically young to mature western part, characterized by a regular, annual discharge to the sea and a larger, topographically old inland part, which contributes to external drainage only irregularly and after periods of exceptional rain. In most years, external discharge is confined to the area westward from the Meckering Line of Mulcahy (1967, 1973). The present study concerns mainly the active, fully fluviatile part of the Avon lying immediately inland from the Darling Range and major tributaries, such as the Dale and Mortlock Rivers, the Talbot and Spencer's Brooks (Fig. 1). Most of this area lies between the 380-508 mm (15-20 inch) isohyets, the 6 wettest months being May to October. River flow is strongly seasonal and usually ceases during summer-autumn.

1. THE AVON MOLLUSCS

Aquatic molluscs were recorded from the Avon soon after the establishment of the Swan River Colony. The collector J. A. L. Preiss (see Glauert, 1948) obtained two species, a thiarid snail and a naiad or freshwater mussel while in the York district between 1838-42. His specimens were presented to C. T. Menke, the German conchologist, and recorded (Menke, 1843) under the names *Melania lirata*, new species and *Unio australis* Lamarck respectively. However the names applied by Menke to these particular specimens are no longer recognized. The first was a homonym of *M. lirata* Benson and was replaced by Brot (1862) with the new

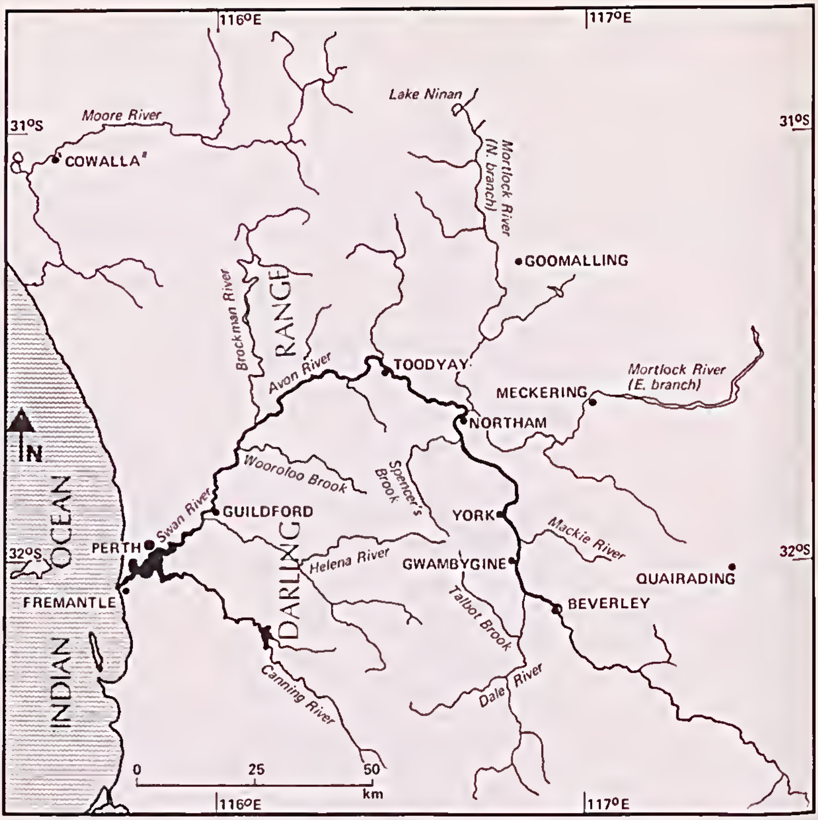


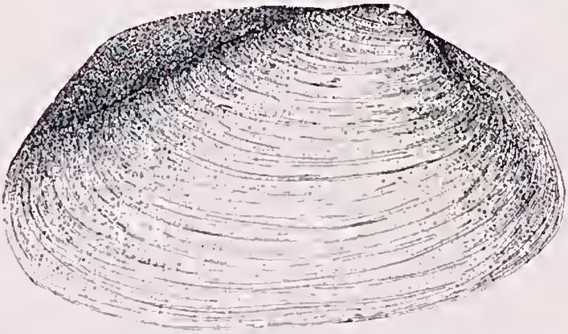
Fig. 1.—Swan-Avon and Moore River systems, south-western Australia, showing principal tributaries.

name *Melania incerta*. Latterly, Australian snails of this group have been placed in the genus *Plotiopsis* Brot. Their taxonomy is unsatisfactory (see McMichael, 1967) and the correct name for the Avon specimens is uncertain but I follow Hedley (1916) provisionally, in the use of the name *P. australis* (I. and H. C. Lea, 1850) for Western Australian occurrences. Menke's other name was a misidentification of the species now known as *Westralunio carteri* Iredale (see McMichael and Hiscock, 1958). The present whereabouts of Menke's specimens is unknown; they may be lost (Dance, 1966).

A second early record from the Avon concerns a specimen of *W. carteri* presented to the British Museum (Natural History) by Mrs. J. Gould (McMichael and Hiscock, *ibid.*), which was probably collected by John Gilbert while in the York or Toodyay districts during 1839-1840. Whittell (1954) records that Gilbert's consignments to Gould in the latter year, at the close of his first visit to Western Australia, included three boxes of shells.

These few records from the pioneering days of the last century (with the sole exception of Main, 1968: 58) appear to comprise all that has been published hitherto on the mollusc fauna of the Avon. Recent collecting has revealed the presence of a further 5 species, making a total of 7 species from the river. These 7 are the bivalves *Westralunio carteri* Iredale and *Anticorbula amara* (Laseron), the prosobranch snails *Potamopyrgus* sp., *Coxiella glabra* Macpherson and *Plotiopsis australis* (I. and H. C. Lea) and the pulmonate snails *Physa* sp. and *Physastra* sp. The status of these species, past and present, is discussed separately.

1. *Westralunio carteri* (Fig. 2).



x 1

This clam has a large, robust shell up to 8 cm long, with a rounded-oblong outline, a dark brown outer surface and a nacreous interior. The animals are active substrate burrowers and feed on detritus and micro-organisms filtered from internally circulated water. Reproduction in *W. carteri* has not been studied but presumably resembles that in other hyriid species (McMichael and Hiscock, *ibid.)*. In these, the sexes are separate and fertilization is internal, the young larvae being discharged from the female as free-swimming glochidia, which must locate and temporarily parasitize a teleost fish. On completion of larval growth, the young clams leave the fish to adopt a burrowing habit in the substrate.

W. carteri is the only naiad to occur in south-western Australia and inhabits (mainly) river pools from the Moore south to about the Kalgan. It is usually a common and conspicuous element of stream faunas. The complete absence of any record of the species from the Avon since the 1840s, either in publications or scientific collections, seemed anomalous, prompting concern for its status there. Regrettably, this concern appears to be well founded for *W. carteri* now seems to have disappeared or become rare at places along the Avon where it used to be common only a few decades ago.

In April 1973, Mr. Brian M. Clifton of "Gwambygine", between York and Beverley, told me that in his younger days around 1912, *W. carteri* was common in Gwambygine Pool but that a decline became evident during the 1940s, the last specimen being seen there by him around 1950. The freshwater catfish or cobbler, *Tandanus bostocki*, declined similarly, the last at Gwambygine Pool to his knowledge being caught in the 1950s. This may be significant in view of the reproductive dependence of the naiad on fish.

Mr. James Masters of "Glen Avon", between Northam and Toodyay, informed me (personal communication, April 1973) that *W. carteri* was fairly common in pools there from 1924 to 1930. Large numbers of shells were evident after winter runs of the river until about 1947 but declined noticeably from then until about 1960. A single dead but fresh specimen was noticed at the Glen Avon Pool in 1971 and odd fragments have been seen occasionally since. He concludes *(ibid.)* that "from the rarity of old shells here, the creature exists in extremely small numbers nowadays". Mr. Masters had noted that the Black Bittern, *Dupetor flavicollis*, had apparently disappeared from the river there since 1952 and had ceased to breed locally by about 1948. The preferred diet of this bird comprised naiads and the Jilgie, *Cherax quinquecarinatus*. Over the same period, Jilgies had decreased greatly in the Avon, though still common in adjacent dams and soaks. This and other changes in bird life along the river have been discussed by Masters and Milhinch (1974).

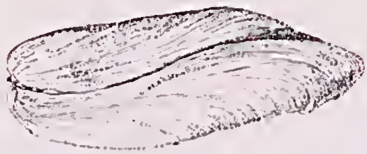
Similar observations have been provided by Mrs. M. Jefferys of "Spion Kop", Toodyay, who recalled seeing naiads at the West Toodyay bridge and at Redbank Pool near Toodyay around the year 1930, but never since then (personal communication, 1971).

In May 1971, several dead shells of *W. carteri* were found in the Avon on both sides of Toodyay by Mr. Dennis F. Pember and students of the Toodyay Junior High School. These specimens were presented to the Western Australian Museum, to become the first representation of the species from the Avon in the Museum's collection. Further empty shells have since been found by Mr. Pember at another pool below Toodyay. These records seem to confirm Mr. Masters' appraisal of the present status of the species below Northam. No living specimen has been reported from there for some years and the long term prospects of whatever population still survives in this tract of the Avon seem at best to be poor.

Apart from Mr. Clifton's recollections of Gwambygine Pool, nothing further is known about *W. carteri* in the Avon above Northam and, with one possible exception, extinction is indicated there and in all local tributaries. I have been informed separately by Mrs. N. I. Docon and Mr. C. Bennett of Beverley that mussels were known by them to occur in Spring Pool, beside the Dale River some 16 km SSW from Beverley in 1968 and 1958 respectively. In April 1973, assisted by Mr. Bennett, I visited Spring Pool but was unable to obtain positive evidence that *W. carteri* was still present. However the water was fresh and unpolluted and the species may well be living there. Subsequently Mrs. Docon located a specimen of *W. carteri* collected at Spring Pool around 1960; this has been presented to the Western Australian Museum. If extant, the Spring Pool population may be the only survivors of *W. carteri* in the Avon System above Northam. I have occasionally found fragments of naiad shells in the Avon near the Wooroloo Brook confluence, but these may be derived from that tributary, where a small population of *W. carteri* occurs.

The salinity tolerances of *W. carteri* and its host fishes are unknown but these may now be exceeded in water along most if not all of the Avon for a significant part of each year. Circumstantial evidence presented below (Figs 10, 11) suggests that raised salinity has been the principal cause of the catastrophic decline of the species since the 1940s.

2. *Anticorbula amara* (Fig. 3).



x 3

This is a small, brown, modioliform clam up to about 16 mm long, with a concave, slightly twisted ventral margin and a toothless hinge. It lives attached by byssal fibres to submerged wood, stones, coarse sand, etc., and presumably is a filter feeder. It inhabits the estuaries of south-eastern and south-western Australia and in the latter has been found tolerant of seawater (E. P. Hodgkin, personal communication, 1975). There are no wholly marine records and, considered as an estuarine species, *A. amara* should be regarded as a brackish-water element (Green, 1968). However in Western Australia, this species ranges far above the limits of tidal influence, having been collected in the Avon as far upstream as Gwambygine Pool and in the Moore near "Cowalla".

Mr. Masters *(ibid.)* considers that *A. amara* has become common in the Avon near his property only in recent years, being rare there during the 1930s. It seems not to have been collected by Preiss at York around 1840, though now conspicuously abundant there. The evidence suggests that, since the turn of the century, *A. amara* has extended its range upstream from the Swan Estuary in response to changes in the river environment. Though present in the Swan near the Helena confluence, *A. amara* seems never to have become established in the latter stream, which has remained fresh throughout this period.

Specimens presumably of *A. amara* were collected in the Swan Estuary at Guildford by the Hamburg Expedition in 1905 and are listed by Thiele (1930) under the name *Modiolus (Fluviolanatus) subtortus* (Dunker). McMichael (1967) considers *Fluviolanatus* Iredale to be a synonym of *Anticorbula* Dall. The anatomical characters of local specimens are unlike those of the Mytilidae (B. R. Wilson, personal communication, October 1971); their affinities seem to lie with the Lyonsiidae.

3. *Potamopyrgus* sp. (Fig. 4).

x 6

This is a minute snail with a shell up to 4 mm high, dark brown, elongate-conical, with slightly convex, smooth whorls; operculum thin, corneous. Records are from streams in south-western Australia between the Moore and Frankland Rivers, it being found on submerged sticks, bark, stones, etc. In the Avon, *Potamopyrgus* sp. is known only from pools in the Walyunga National Park. These are situated in the Darling Range immediately below the confluence with the comparatively fresh Wooroloo Brook; records date only from 1969. It seems likely that this species once occurred more widely along the Avon and tributaries but positive evidence of this is lacking.

4. *Coxiella glabra* (Fig. 5).

x 3

One of the Salt Lake Snails (Macpherson, 1957), this species has a small, smooth, elevated, light brown shell, usually with a decollate spire and a height of up to 7 mm; occasional non-decollate shells may reach to 11 mm. The operculum is corneous and thick. *C. glabra* inhabits saline to brackish lakes and streams from the Murchison district south into the central wheatbelt. From the Avon River System, it is known only from one sample collected in May 1958 from "a creek bed beside the Goomalling road 8 miles N of Jennacubbine", evidently the north branch of the Mortlock River. It is uncertain whether this record represents a long standing presence in the Mortlock or a recent extension of range from salt lakes in the district, such as Lake Ninan, in which *C. glabra* occurs and which connects with the Mortlock near Wongan Hills (Fig. 1).

5. *Plotiopsis australis* (Fig. 6).

x 1.5

This is a small to medium sized snail with a shell up to 30 mm high, the spire high, apex decollate, and with shouldered convex whorls, which usually bear both spiral and axial sculpture. The columella is thickened and the aperture roundly cut out at the base. It is coloured yellowish-brown, with or without reddish axial streaks; colours are often concealed beneath a blackish-brown encrustation. The operculum is corneous, thick and dark brown. *P. australis* occurs in river pools generally throughout Western Australia south to the Avon.

Since its discovery at York by Preiss around 1840, *P. australis* has not been recorded again from there or from any further-upstream locality; it has never been noticed by Mr. Clifton at Gwambygine Pool. Mr. Masters informs me *(ibid.)* that it "existed in extremely large numbers in Avon pools in this area (between Northam and Toodyay) until at least 1947 or 1948 and could still be found . . . to at least 1956". So common was it during the 1920s that shells were bagged and fed to the farm poultry. In contrast, present populations along this section of river appear to be scattered and live specimens uncommon. Mr Masters estimates that *P. australis* and *A. amara* have changed inversely in abundance near "Glen Avon" over the past 50 years.

In April 1973, I found numerous shells of *P. australis* in what remained of Burlong Pool, near Northam. All were dead and apparently only recently so; this appears to be the most-upstream record for the species since the time of Preiss. Living *P. australis* are still common in the Avon where it traverses the Darling Range, e.g., near the Wooroloo Brook confluence, and range downstream to Guildford. Elsewhere along the Avon, the species has declined in numbers and contracted downstream similarly to *Westralunio carteri*, though apparently later and to a somewhat lesser degree. The period of greatest decline seems to have been the 1950s.

6. *Physa* sp. (Fig. 7).

x 3

This is an introduced pond snail with a small, ovate, pale-brown shell, up to 14 mm high, sinistrally coiled, with a short, acute spire and smooth, polished, translucent whorls. There is no operculum. The shell resembles that of the following species, *Physastra* sp., and reliable separation of the two depends on anatomical characters. The animal of *Physa* sp. has a series of finger-like processes along the mantle margin; seen through the shell, the mantle has a reticulate pattern and the blood is colourless.

This appears to be an introduced species, first recorded from Western Australia at Perth in 1952 (Hubendick, 1955) and now acclimatized throughout much of the south-west of the State. It was collected from the Burlong railway dam near Northam in 1968 and from the Avon near the Wooroloo Brook confluence in 1969. *Physa* sp. is commonly kept in local aquaria and its acclimatization probably followed release from these. The Physidae were originally Holarctic in distribution and local stocks are probably derived from either Europe or North America.

7. *Physastra* sp. (Fig. 8).

Like the preceding species, this pond snail has a thin, sinistrally coiled shell but may reach a height of 28 mm. Fresh shells are usually a medium to pale shade of brown and are more opaque than those of *Physa* sp.; there is no operculum. The mantle margins are smooth, lacking processes and the blood is red. *Physastra* sp. is a common, generally distributed snail in fresh inland waters throughout south-western Australia.

However the only known occurrence from the Avon system above the Darling Range is in Spring Pool near Beverley. This pool, which stands above and beside the main channel of the Dale River, holds fresh water. *Physastra* sp. has recently been collected from the Brockman River at Chittering and there is a sample in the W.A. Museum collection from "a soak near Beverley", presented in 1950. Whether the species was ever generally present along the Avon is uncertain but the evidence of these few peripheral occurrences, together with its general distribution elsewhere within the region, suggests that this was probably so.

8. An ancylid freshwater limpet of minute size, up to 5 mm long and tentatively referred to the "form group" *Ferrissia (Pettancylus) petterdi* (Johnston) after Hubendick (1967) occurs widely in lakes, streams and other water bodies of south-western Australia. There are no known records from the Avon, but this may reflect either the unobtrusive nature of the animal, or insufficient collecting, or a recent decline. Distribution records from the Western Australian Museum collection suggest that *F. (P.) petterdi* either is or was probably part of the Avon fauna and justify its qualified inclusion in this summary.

2. THE CONDITION OF THE AVON

(a) THE AVON AS IT WAS

The first Europeans to sight the Avon River did so in August 1830 near the impending site of York. The weather was wintry and the river in flood. Their leader, Ensign Robert Dale, recorded in his journal (Dale, 1833a) that "The water was discoloured and muddy with a rapid current and enclosed between banks moderately clothed with trees and shrubs". No other reference was made to water quality. A later report (Dale, 1833b) refers to brackish and salt water pools in the upper reaches of the Avon during October. Pools of varying salinity, from fresh to salt, along the Avon in 1836 are referred to by Bunbury (1930: 28, 32, 43, 50).

The central Avon valley was one of the earliest districts to attract settlers from Perth. The first of these "set out in September 1831 to take possession of their grants. Soon all the river frontages from the present towns of Beverley to Northam were taken up . . ." (Mouritz, 1956: 46). Private land extended "right into the river bed", according to James (1893), a condition that generally prevails to this day. Early reports on the Avon lack chemical data but suggest that, even in the early years of European settlement, water quality varied perceptibly with time and place but this did not prevent its being used extensively by the settlers. Describing the Avon at Toodyay in the 1870s, Hammond (1936: 123) recalled that "The very fine pools of fresh water in the river in the summer time made the whole district suitable for raising stock of all kinds".

In a report to Parliament on water supplies along the Avon, James (1893) found the river water at York to be unsuitable for domestic purposes, particularly when in flood, because of overflow (presumably saline) water from lakes near the river's source; however a western tributary near York was found to have "remarkably pure water". At the Mortlock confluence just below Northam, James noted that the Avon became saline and undrinkable. However water in pools by Mt. Noondening (near "Glen Avon", between Northam and Toodyay) was "fairly good, having a slightly sweet taste, quite suitable for house or stock purposes". Burlong Pool was then "a vast sheet of water fully one third of a mile long. The river at this point has well defined, fairly high banks; this pool is now running full and the water is of excellent quality, quite suitable for domestic purposes, although it carries with it at this date (March 1893) a slight taste".

James quoted a local resident who had known Burlong Pool for 41 years, i.e. since 1852, asserting that it had never been dry in that time "and with ordinary rain was perfectly fresh, pure water as it receives rain from Spencer's Brook (six miles distant) and four other large tributaries, which make the Avon River drinkable at all seasons" *(ibid.)*.

Reports on the working of the Western Australian Government Railways for the years 1892-1902 show clearly the reliance of the Department during those years on water from the Avon River for steam locomotives operating out of Northam. The railway reached Northam in October 1886; initial sources of water are not specified but during the period 1892-1895, the water service at the West Northam locomotive depot was connected by pipe with Burlong Pool, situated about 2 miles (3.2 km) upstream (Report for 1892-1895, pp. 9, 10).

During 1896-1897, the Burlong Railway Dam was constructed on a minor tributary of the Avon, a little west of Burlong Pool and from then until the arrival of the Goldfields Water Scheme at Northam in April 1902, the railway drew on both the dam and pool for boiler water. For periods during the summers of 1896-1897 and 1897-1898, when dams dried up along the Eastern Goldfields line, Burlong Pool appears to have been the principal source of boiler water for locomotives operating east from Northam.

No chemical data from analyses of Burlong Pool water over this period seem to have been preserved but railway boiler water was preferred to carry not more than 430 parts per million (30 grains per gallon) sodium chloride according to Simpson (1928), and could be accepted at no higher than 500 p.p.m. (35 g./g.) if necessary (Mr. H. Groom, personal communication, May 1973). This may indicate an approximate upper level to salt concentration in Burlong Pool water during the 1890s. For domestic and stock purposes, such water would be regarded as fresh.

In August 1894, at a time of acute pressure on the government to provide a reliable water supply for the Eastern Goldfields, a Mr. John

Maher applied to the Minister for Mines for rights to impound and pipe water from the tributaries of the Avon near Northam to Coolgardie. Maher's letter appeared a month later in *The West Australian* of 17th September. An editorial on the following day, predictably cool toward the Maher scheme, referred to the Avon as "the source from which we shall draw the means for providing the many townships along its banks with water for general use. The municipalities have a lien on the waters of the Swan for their municipal wants. Moreover the owners of the fertile lands lying along the banks cherish expectations that by means of its pools irrigation will be made a cheap and simple matter for them". A letter from a Maher supporter published on 29th September advocated a system of dams and weirs on the Avon.

The Southern Cross Herald of 21st September 1894, supporting the Maher scheme, contended that "if the Avon near the Burralong (presumably Burlong) Pool, Northam, is dammed up, an inexhaustible supply of the precious fluid would be procurable". On 28th September, this newspaper published an interview with Maher concerning his "Avon-Coolgardie Water Scheme". Proposals in 1894 to dam the Avon near Toodyay and Northam are discussed by Erickson (1974: 317).

The government adopted a proposal made by C. Y. O'Connor to dam the Helena River to supply the Goldfields and Maher did not proceed with his scheme. However these contemporary records show that towards the turn of the century, the Avon and its western tributaries, especially near Northam, were regarded as acceptable sources of domestic, agricultural and industrial water. In the absence of positive mollusc records from this period, it is safe to assume that the fauna of the Avon was the same as that found by Preiss and Gilbert a half century earlier. *Westralunio carteri* and *Plotiopsis australis* were undoubtedly present in this fauna and probably *Potamopyrgus* sp., *Physastra* sp. and *Ferrissia (Pettancylus) petterdi* were likewise; at this time, *Anticorbula amara* may have been confined to estuarine waters.

(b) THE AVON TURNS SALT

By the turn of the century, signs of deterioration in the condition of the Avon were appearing. Wood (1924) recalled that "about 1897, in the Northam-Toodyay district, I heard it suggested that destruction of the native vegetation turned the water in the creeks salt; and about 1904 I thought that I could see evidence of increase in salinity in the Goomalling Agricultural Area". The connection between the clearing of catchments and salinity increase was also noted by E. S. Hume, Chief Mechanical Engineer, in the *Report on the working of the Government Railways for the year 1908-9*.

From about 1893 to 1910, a steam-powered flour mill operated at Beverley, using boiler water from the Avon. The late Mr. A. Oliver of Beverley, whose father was manager, informed me (personal communication, June 1973) that "salinity was an increasing problem from about 1907 and . . . every few months there would be a shut down of the mill whilst my father and others removed salt encrustations from the boiler".

Upstream from Toodyay, the drainage basin of the Avon has been very extensively cleared for agriculture, probably to a greater extent and for a longer time than any other in Western Australia. Destruction of the original deep-rooted *Eucalyptus-Acacia* woodland and its replacement with shallow-rooted seasonal crops and pastures has raised the water table and greatly increased the salinity of stream discharge, here as elsewhere in south-western Australia (Mulcahy, 1973; Peck and Hurle, 1973). Na^+ and Cl^- are the predominant ions in the groundwater throughout the region. They are believed to have been derived largely from the rain as "cyclic salt" (Weller, 1928; Williams, 1967). Many Avon tributaries, especially the smaller ones, have been entirely cleared of standing vegetation; others have been devegetated through salting following the clearing of the surrounding land. The extension of agriculture eastward from the Meckering Line has increased the frequency of saline lake discharge into rivers including the Avon, thus further raising their salinity load (Mulcahy, 1973).

I have not attempted to establish the proportion of the Avon catchment that has been cleared but present data on some agricultural shires, being representative "Avon country", to indicate the approximate degree to which this has proceeded. Rural land utilization statistics issued by the Bureau of Statistics show that by 1971-72 in the wholly agricultural shires of Goomalling, Cunderdin, Brookton and Quairading (taken together) about 85% of farming land had been cleared. Most of the remainder seems to have been used for stockgrazing and very little of the original woodland would now remain in an unmodified condition. The shires of Toodyay, Northam, York and Beverley retain forested water catchment areas in their western parts and, statistically, have higher proportions of uncleared land than the foregoing. However their agricultural eastern parts appear to have been cleared to a similar extent. Masters and Milhinch (1974) estimate that less than 5% of the area of Northam Shire remains in virgin condition.

By 1932, it appears that salinity in the Avon at Northam had increased considerably over the preceding 30 years. An analysis by the Railway Department in August of that year showed 1,278 p.p.m. (90 gr./gal.) of "salt", a concentration more than double the accepted maximum for locomotive water. By contrast, the streams flowing into Burlong Dam at the same time averaged only 71 p.p.m. (5 gr./gal.) of "salt". Older water

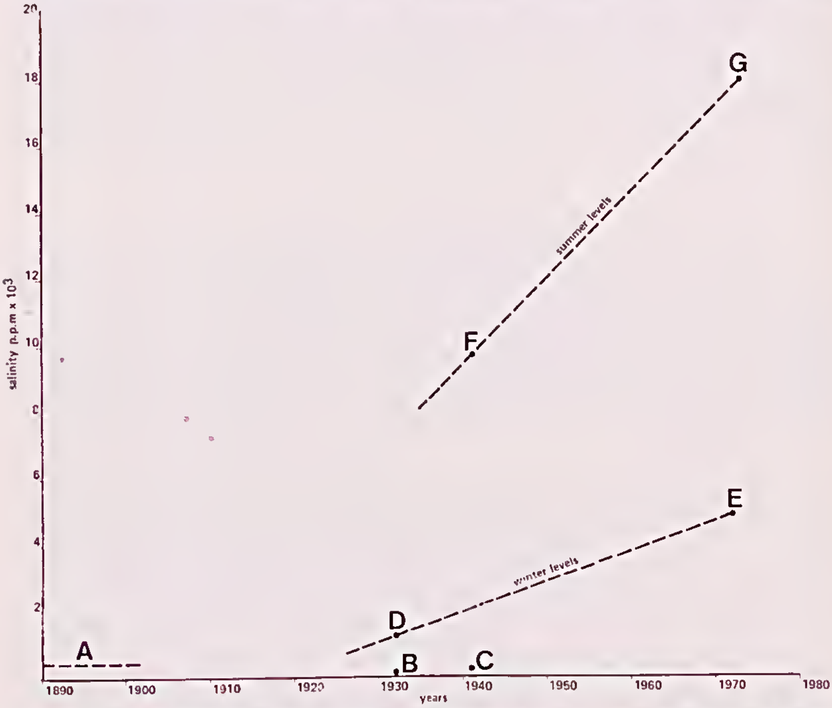


Fig. 9.—Salinity levels (sodium chloride) in the Avon River and Burlong railway dam, Northam, 1890-1973. A maximum acceptable level for locomotive boiler water (Simpson, 1928). B Burlong railway dam, August 1932 (winter). Source W.A.G.R. C Burlong railway dam, January 1941 (summer). Source W.A.G.R. D Burlong Pool, August 1932. Source W.A.G.R. E Avon R. above Mortlock confluence, August 1972 (winter). Source P.W.D. F Burlong Pool, January 1941. Source W.A.G.R. G Avon R. above Mortlock confluence, April 1973 (autumn). Source P.W.D.

drawn from the bottom of the dam carried 162 p.p.m. (11.4 gr./gal.). These tests were repeated by the Department in January 1941; Burlong Pool water then contained 9,734 p.p.m. (685.5 gr./gal.) of "alkaline chlorides" and drew the comment from the analyst that "This water is quite unsuitable even for boiler washout purposes". Again, by contrast, Burlong Dam water sampled a few weeks earlier contained only 256 p.p.m. (18.04 gr /gal.) of "alkaline chlorides" (Mr. H. Groom, personal communication, May 1973).

These data, from Railway Department records, point to rapidly diverging salinity levels over the decade 1932-1941 between Burlong Dam and Burlong Pool. The low concentrations from the dam on these two occasions lend credence to the subjective impressions of James *(ibid.)* on the purity of water from the Avon's western tributaries in the 1890s.

Concentrations of sodium chloride in Avon water at Northam (from a site above the Mortlock confluence and presumably comparable with Burlong Pool water) determined by the Public Works Department for the period November 1971 to May 1973 range from 4,850 p.p.m. (328 gr./gal.) in August 1972 to a maximum of 17,800 p.p.m. (1,254 gr./gal.) in April 1973. A combined graph of the abovementioned salinity data from governmental sources in Fig. 9 suggests the rate and timing of change in the composition of Avon water at Northam since the turn of the century. A substantial transformation had evidently set in by 1941 and a large part of this probably occurred during the preceding decade.

On the timing of these events, some observations of Mr. Masters may provide further evidence. He has noted that from 1935-1944 no major flood from the eastern wheatbelt lake system entered the Avon, the floods of 1939 and 1943 originating in the relatively fresh western watershed. The major floods of 1945 and 1946 were the first occasion for over 10 years, when the wheatbelt lakes overflowed, discharging a large quantity of salt accumulated there in the wake of the post-1920 agricultural development of the region. Hydrologic and other deterioration of the Avon was intensified as a result of these two floods (pers. comm., Dec. 1975).

Mr. Masters has kindly made available some data (Fig. 10) on salinity of river water near his property. He writes: "Water salinities in the major pools between 1930 and 1944, at least between Northam and Toodyay,

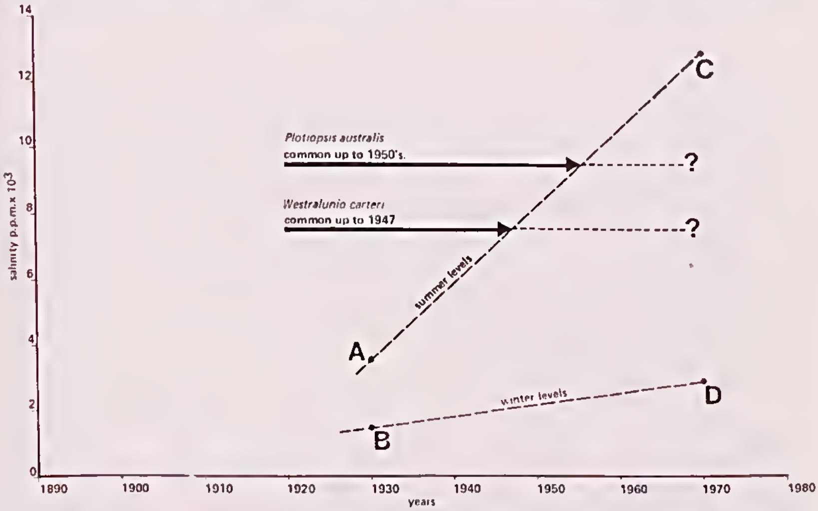


Fig. 10. Approximate range of salinity levels ("total salts") in Glen Avon Pool, between Northam and Toodyay, 1930-1970. A-C dry season levels. B-D wet season levels. Onset of crises affecting 2 species of molluscs shown by arrows.

ranged between about 1420 and 3550 p.p.m. (100 and 250 gr./gal.) total salts during the course of each year. Since about 1950, this pool at "Glen Avon", at least, has a range of salinity of about 2,840 p.p.m. (200 gr./gal.) in flood to as high as 12,780 p.p.m. (900 gr./gal.) at the end of a long dry summer, and the higher figure is usually reached in years when lakes from the inland wheatbelt have overflowed strongly into the spring months. This year (March 1973), without any inflow from the eastern lake system, the salt content at the moment is approximately 6,390 p.p.m. (450 gr./gal.) and this is the usual characteristic of this pool in drier years without runoff from the eastern watershed".

The "Glen Avon" data are similar to those from Northam and indicate a direct cause and effect relationship between rising salinities and the observed changes in aquatic life along the Avon over the past half century. There is no evidence that this increasing rate of salt discharge has yet peaked. The continued presence of abundant *Plotiopsis* and *Potamopyrgus* in the lower Avon below Toodyay suggests that fresh water received from tributaries and seepage in the Darling Range provides some protection for these species in that part of the system. A salinity profile similar to that reported for the Blackwood River by Morrissey (1974) evidently exists within the Avon.

(c) LIVESTOCK POLLUTION

Contamination of ground and surface waters by animal wastes is an acknowledged pollution hazard in some parts of the world, notably North America, where intensive livestock farming is widespread, but has received little attention to date in Australia (Boughton, 1970). The havoc which it can inflict on aquatic life under certain conditions is shown by some recent experiences along the Avon.

Early in February 1971, a tropical cyclone brought heavy local rain to the Toodyay district, a good deal of which ran quickly off the dry paddocks and into the Avon. Much organic material, including animal waste, was washed into the pools. About a week later, the press reported that an estimated 1,000 fish, mostly Cobblers, and some Jilgies had been found dead in Redbank Pool. This was attributed to oxygen depletion of the water and presumably eutrophication (*The West Australian*, 9th February, 1971, p. 5).

A similar sequence of events, probably in the wake of the same cyclone, was observed by Mr. V. Thorbjornsen of Northam. Here, heavy rain on adjacent dry paddocks washed a large quantity of organic material into Burlong Pool so as to virtually blanket the surface with a floating mass, mainly sheep manure. The water turned dark and smelly and dead fish appeared along the banks (personal communication, April 1973).

At the beginning of April 1973, accompanied by Messrs. A. Oliver and C. Bennett of Beverley, I visited a section of the Dale River near Mile and Reserve Pools, SSW of Beverley. No rain had fallen in the district for some time but nevertheless a small flow of clean, slightly brackish but potable water was moving through Reserve Pool. This probably originated from springs located upstream near Spring Pool. Fish and other fauna were evident in the pool, though no molluscs were seen. One week later a thunderstorm brought the first autumn rains to the district, with heavy local showers.

On a return visit one week after the rain and two weeks after my first visit, I found the same stretch of river grossly polluted. The water was dark brown and smelt strongly of animal waste, evidently sheep manure. Between Reserve and Spring Pools the banks were strewn with dead and apparently dying Nightfish *(Bostockia porosa)* and Pigmy Perch *(Edelia vittata)*. A Jilgie, without chelae, presumably as a result of stress, was taken from the water. At Mile Pool, vast numbers of dead and dying shrimps *(Palaemonetes australis)* littered the banks. Others were swimming erratically on the surface at the water's edge, some leaping out to join those on the banks. Presumably this behaviour was in response to the fouled condition of the water.

These three episodes, involving catastrophic destruction of fauna, point to a second major threat to the biota of the Avon, or that part of it that has been able to tolerate prevailing salinities. The observations cited relate only to small sections of the river system but the ingredients are ubiquitous and it is reasonable to believe that such events now occur regularly along much of the Avon and tributaries during the summer-autumn months. This is the time of year when the fauna would probably be under greatest stress from the effect of raised salinities.

Since the 1830s, the Avon pools have been used for the watering of livestock, particularly in the dry season, and in earlier periods of low stock density and salinity little if any harm would have been done to the aquatic environment and biota. Over the last 30 years, however, since the introduction of subterranean clover and other innovations, the sheep population of the Avon districts has risen about three-fold (Bureau of Statistics data) and no doubt total stock density on the river and adjoining land has increased substantially over this period. No figures are available, but the quantity of animal waste deposited during a dry season in the main and tributary channels and adjacent land must be considerable. The sudden reactivation of this material by summer or autumn rains can lead to crises of deoxygenation and eutrophication in the pools, which are the dry season refuges for the fauna.

The traditional practice of permitting livestock generous access to the pools, channel and banks of the Avon and its tributaries, initiated in a bygone age of low stock densities and relatively fresh water, should now be reappraised in the light of its apparent significant contribution to the advanced degradation of the river environment.

It is conceded that the above comments are largely intuitive and lack the authority that would derive from a series of more representative, controlled observations; however their relevance to the overall problem of the ecologic stability of the Avon is undeniable. The uncertainties that exist in relation to this question only emphasize the fact that no authoritative investigation into the combined effect of increased salinity and animal waste pollution on river biotas has ever been undertaken in Western Australia. Other potential sources of river pollution, less amenable to direct observation, include chemical fertilizers used to excess, weedicides and pesticides, but nothing is known of their presence in the Avon and effects, if any, on the biota.

(d) A RIVER OF SAND

In its mature middle section the bed of the Avon originally comprised alternate deeps and shallows which, in the dry season, took the form of stable, permanent pools separated by dry sandy channels. The latter supported a substantial growth of trees, bushes and other vegetation, notably species of *Casuarina, Melaleuca* and *Eucalyptus*, the roots of which, together with a great quantity of surficial and buried woody debris, served to stabilize the substrate. Though no data are available on which to base precise comparisons, there can be little doubt that the near-total clearing of the catchment has substantially increased the concentration and probably also the volume of surface runoff after rain. These factors have probably intensified the erosion of sediment, particularly from higher land, and contributed significantly to the accumulation of sand in the bed. The continual access of livestock to the banks, channel and tributaries is likely to have aggravated this process.

The Avon towns were initially laid out at a time when the discharge characteristics of the river, unmodified by man, were poorly understood. Old Toodyay, located in close proximity to the Avon, had to be abandoned in favour of the present site following a sequence of floods of growing severity through the 1840s and 50s (Erickson, 1974). Buildings were flooded in Northam as early as 1862, but the example of Old Toodyay, based on recognition of the need to give the river adequate room, seems not to have been followed and the town centre was allowed to develop with the protection of a levee on flood-prone land. The inevitable crisis arrived in 1955, when much of central Northam was inundated following heavy cyclonic rain. This seems to have been the last occasion on which some relatively inexpensive reorganization of the town to accommodate the river might have been entertained. Regrettably, however, an opposite policy was adopted.

In 1956, the government of the day (the Premier being the Member for Northam) initiated the "Avon River Training Scheme", which sought to improve the river's flood discharge capacity by the mechanical removal of sediment and vegetation from the channel between Toodyay and Brookton. This operation, seemingly of indefinite duration, has been confined to the main channel, that is, the area where the *symptoms* of hydrologic and sedimentologic instability are most concentrated and without regard for those parts of the catchment where the underlying problems of concentrated runoff and erosion are generated. Whatever the reasons, it is evident that the channel substrate has become less rather than more stabilized and this has given rise to public misgivings as to the merits of the scheme.

Over its 20 years of operation, no official evaluation of the "training scheme" has been released but it is clear that one major negative consequence has been the creation of a large body of unstable sand in the channel between York and Toodyay. Some once-permanent pools have been buried by this sand and others partly so, including the once extensive and deep Burlong Pool (see newspaper references, *Daily News* and *West Australian)*. Without some new initiative, it seems that the obliteration of most if not all of the pools in the Northam district is only a matter of time. In the past, the pools served as summer refugia for aquatic life. Now not only the fauna but the very existence of the pools, once regarded as among the district's greatest assets, is in jeopardy. Their loss would constitute a further major step in the degradation of the initially fragile riverine environment of the region. If the aim of the "training scheme" was to convert the central Avon into a mere agricultural storm-water drain, then by this narrow engineering premise it could be regarded as a qualified (as yet untested) success, apart from being financially wasteful and unnecessary. But as an operation aimed at river conservation, its effect has been disastrous. The scheme was initiated and pursued without regard for the need for any biological investigation of the Avon and it is probable that part of the biota has now been irrevocably lost as a direct consequence.

The changes to parts of the Avon associated with the "training scheme" are drastic and visibly conspicuous and therefore disturbing to those who knew the river in better times. However it should be realized that these changes are only the most recent episode in a process of accelerating multiple disturbance to the river's ecosystem that has been operating since before the turn of the century.

3. WANTED: A NEW APPROACH

The old Avon, together with the woodlands that sustained it, is gone for ever; agricultural development of the catchment has brought permanent, irreversible changes to the region. The river's present and future need seems to be for an informed, conservation-management policy that will progressively establish a degree of stability and harmony with its man-made environment and at the same time conserve and restore as much as possible of the original riverine flora and fauna. Any further change would need to be of a kind beneficial to the river environment. (Indeed a cynic might argue that little more *could* now be done to harm the river, intentionally or otherwise). Our readiness to see it in such a way should be helped by the realization that the Avon, once an economic and recreational asset, has been transformed into a financial and environmental liability; a stabilized, restored Avon would mean, in time, a better human environment for the district. A new approach is indicated, but in practical terms are there any real alternatives to present practices and policies? There is little cause for optimism in official and community attitudes; beyond the need to protect the towns from flooding, no aims have been defined, no expectations fostered.

A listing of facile "solutions" to the problems of the Avon is not called for here. Before they could be considered, attitudes and values among all concerned parties would have to be established and clarified, the problems recognized and defined. However I propose to mention briefly some possibly useful ideas on the subject in support of the view that there are alternatives to the present policy of attrition.

Initially, data would need to be gathered on all aspects of the hydrology, sedimentology and biology of the Avon, its tributaries and the catchment generally, including land-use practices in the region. In particular, the system's net rate of salt discharge (Peck and Hurle, 1973) could be assessed, as could the totality of factors that contribute to flooding. Innovations regarding salination and flood control, such as revegetation, could be devised. Soil erosion in the district is currently judged solely on agricultural criteria; whether these are also adequate to protect the Avon from excessive long-term sand accumulation may be relevant. Further implementation of the "training scheme" should be stopped and the effort thus saved diverted into the search for more enlightened and comprehensive policies of river management. At the same time, the Northam levee system should be improved. Flood-prone areas of this and other towns could be proclaimed and all new building in them prohibited, a measure that is at least a century overdue.

In the past, the Avon pools were important for the watering of livestock, but now this is often no longer feasible and in general no longer necessary. Most farms in the district now have access to reticulated water from the Darling Range and with this alternative source available, or potentially so, it may be time to propose the future exclusion of livestock from the river and major tributaries. Studies of the effect of livestock trampling on the sedimentologic stability of channels and banks, as well as the effects of animal waste pollution on aquatic life seem to be desirable. An attempt at a comprehensive biological survey of the Avon could be made and a policy adopted for a regular monitoring of the biota.

In the wheatbelt communities of Western Australia there is now some recognition, even regret, that the region was cleared to excess. With regard to this sentiment and to the conservation needs of the Avon, a case could be made for a study of ways and means whereby a special Avon River Reserve or even National Park could be established, comprising the channel, banks and a generous width of land on both sides. This could comprise both public and privately owned land, the former created by purchase, the latter by voluntary concession; for the loss of productive land in the latter case, compensation borne by the State would be justified. Such a reserve, a long-term project, would need to be fenced to exclude livestock; channel sands could be re-stabilized and pool formation assisted where possible. Native vegetation could be restored. Animal vermin would need to be controlled and noxious and aggressive weeds excluded. The reserve could be extended progressively out from the main channel and along the larger tributaries.

The Avon's problems are complex and regional in scope; their amelioration in ways that would lead to the restoration of the river, rather than its further degradation, would seem to require the combined resources of private individuals and organizations as well as governments at all levels. A managerial body with an overview of the total situation, on which local communities would be directly represented, would be essential for continuity and effective action.

Returning to the real world, there can be few who would be surprised if the future of the Avon turned out to have little or no resemblance to the scenario lightly sketched above. However the central issue of the protection of the integrity of river environments in south-western Australia cannot be concealed much longer, for although the Avon is the most degraded of our rivers, it is not the only one so affected. There is faunal and other evidence that the Moore has been overtaken by a hydrologic crisis since the 1960s; others, such as the Murray, Collie and Blackwood are becoming increasingly affected by salination. The conflicting interests of water conservation, nature conservation, agriculture, bauxite mining and wood-chipping, aggravated by the spread of die-back disease, will not be easily resolved and constitute a problem of unprecedented magnitude. Recognition that our freshwater faunas are threatened has been late in coming; that their preservation is directly linked with the stability of our water catchments and hence with the future basic needs of urban and rural communities in south-western Australia may yet swing the balance in favour of more effective conservation measures on behalf of our limited freshwater resources. If the example of the Avon serves only to create more concern for the fate of the rivers in the region, its destruction will not have been completely in vain.

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TABLE 1.—SYNOPSIS OF APPARENT OR INFERRED CHANGES IN THE OCCURRENCE AND DISTRIBUTION OF MOLLUSCS IN THE AVON RIVER, 1840-1975.

Species	Past status	Present status
1. *Westralunio certeri*	Originally common and widespread. In pools above York, common up to the 1940s, then in decline; last seen about 1950 in Gwambygine Pool. Between Toodyay and Northam common up to about 1947, in decline to ebout 1960, subsequently rere.	Probably extinct ebove Northam except for remnant population in Spring Pool, by Dale River. Below Northem rare, perheps close to extinction. Present but uncommon in Wooroloo Brook, 1971.
2. *Anticorbula amara*	Prior to 1900 probably wholly estuarine. Below Northam rare in the 1920s, increesingly abundant since.	Common in the Swan estuary and abundant upstream to beyond York.
3. *Potamopyrgus* sp.	Unknown; possibly once widespread.	Living near the Wooroloo Brook confluenco since 1969.
4. *Coxiella glabra*	Unknown but may havo boen originelly rostricted to seline/brackish lakes in the northern headweters of the drainage basin; present in the Mortlock (North Branch), 1958.	No records since 1958.
5. *Plotiopsis australis*	Originally common and widespreed at least upstream to York, but not reported from there since about 1840. Between Northam-Toodyay, common up to the 1950s; subsequently in docline there.	Probably extinct from York upstream; recently living in Burlong Pool but now possibly extinct betweon Northam and York. Uncommon between Northam-Toodyay. Common in Darling Range, notably around Wooroloo Brook confluence and downstream to Guildford.
6. *Physa* sp.	Introduced specios.	In Burlong railway dam, 1968; in Avon near Wooroloo Brook confluenco, 1969.
7. *Physastra* sp.	Unknown but probably once widespread. Collected in 1950 from "soak near Beverley".	In Brockman Rivor and in Spring Pool by Dele River.
8. *Ferrissia (Pettancylus) petterdi*	Unknown; past presenco inferred.	Unknown; recent decline or extinction possible.

NEW BREEDING RECORDS OF THE BANDED STILT IN WESTERN AUSTRALIA

By NICHOLAS KOLICHIS, Osborne Park

C. F. H. Jenkins (1975) has given a brief summary of the remarkable history of discovery of the nesting habits of the Banded Stilt *(Cladorhynchus leucocephalus)* in inland salt lakes, and of the latest record, at Lake Ballard, near Menzies, in 1973.

Some additional early nesting records, attempted and actual, not cited by Mr. Jenkins, may be mentioned.

On November 8, 1960 in the Yalgoo district Ivan Carnaby found 40-50 depressions in preparation for nesting by this species on an island in Wagga Wagga Lake, but when he and P. J. Fuller (1963) returned on November 26 nesting had been abandoned, presumably because the lakes were drying. About 400 Banded Stilts were present on both visits.

On August 11-17, 1971 Mr. W. H. Butler (pers. comm.) saw a flock of Banded Stilts, adults and young, at a claypan 30 km south of Durba Spring on the Canning Stock Route and others at a claypan 5 km north of Well No. 11. He collected an immature specimen (now in the American Museum of Natural History, New York). Presumably they had nested nearby, probably at Lake Disappointment. This lake would have been filled by heavy rain in May of that year.

In July 1974 Mr. A. Middleton (pers. comm.), while a resident at Menzies, saw a large number of chicks and adult Banded Stilts on the